Compton-thick AGN and the Synthesis of the Cosmic X-ray Background: the *Suzaku* Perspective

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We discuss the abundance of Compton-thick AGN as estimated by the most recent population synthesis models of the cosmic X-ray background. Only a small fraction of these elusive objects have been detected so far, in line with the model expectations. The advances expected by the broad band detectors on board *Suzaku* are briefly reviewed.

§1. Introduction

Despite extensive observational efforts, the population of heavily obscured, Compton-thick AGN remains elusive, especially at high redshifts, preventing a complete census of accreting supermassive black holes (SMBHs). While Compton-thick (CT) nuclei were shown to hide in about half of local Seyfert 2 galaxies (Risaliti et al. 1999, Guainazzi et al. 2005), observations of heavily obscured objects beyond $z \sim 0.1$ are very sparse (see Comastri 2004 for a review) and their abundance can be constrained only by indirect arguments. One argument is the comparison between the mass function of local SMBHs with the one expected if they accreted most of their mass during past AGN phases (Marconi et al. 2004). Another, and probably more stringent, argument is the residual emission at 30 keV in the spectrum of the cosmic X-ray background (XRB), which is left after removing the contribution from the better known population of less obscured, Compton-thin AGN. The residual 30 keV XRB emission can indeed be modeled by assuming a population of CT AGN as large as that of moderately absorbed ones over a broad range of redshifts and luminosities (see Gilli, Comastri & Hasinger 2007, hereafter GCH07, for a recent work). In particular, this residual emission is mostly filled by "mildly" CT objects (defined as those with $10^{24} < N_H < 10^{25}$ cm^{-2}) in which the direct, primary emission is visible above $\sim$ 10 keV, rather than by "heavily" CT objects ($N_H > 10^{25}$ cm^{-2}), in which only reflected radiation is visible at high energy, and are therefore significantly less luminous than the formers at 30 keV. As a consequence, the number of heavily CT AGN is poorly constrained even by population synthesis models and is generally assumed to be similar (equal in GCH07) to that of mildly CT objects, as suggested by the results of Risaliti et al. (1999). Because of the strong selection effects due to absorption, only a small percentage of CT sources have been observed

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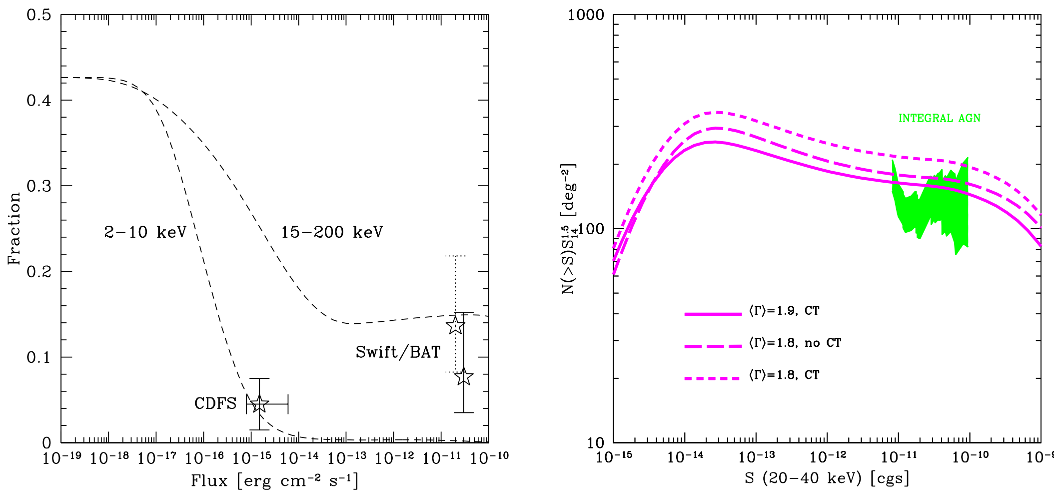

Fig. 1. *Left* : The fractions of CT AGN in the GCH07 baseline model as a function of the 2-10 keV and 15-200 keV limiting fluxes compared to those observed in the CDFS (Tozzi et al. 2006) and in the *Swift*/BAT catalog (Markwardt et al. 2005). The upper *Swift*/BAT point is corrected for incompleteness. Note the steep increase expected at fluxes below the current sensitivities and the identical CT fraction in the two bands at extremely faint fluxes, where *all* AGN should be detected. *Right* : The predicted 20-40 keV AGN counts (see Section 2) normalized to an Euclidean Universe and compared with those measured by *INTEGRAL* (Beckmann et al. 2006).

in current X-ray surveys. In the Chandra Deep Field South (CDFS) only about 5% of the detected AGN have been identified as CT candidates (Tozzi et al. 2006). In the recent *INTEGRAL*/IBIS and *Swift*/BAT surveys performed above 10 keV, where the absorption bias is less effective, a higher fraction is observed ($\sim 10-15\%$, Markwardt et al. 2006, Beckmann et al. 2006). This is already remarkable, if one bears in mind that X-ray surveys above 10 keV are still limited to very bright fluxes ($\sim 10^{-11}$ erg cm^{-2} s^{-1}). As shown in Fig. 1 *left*, these small observed fractions are in good agreement with those expected if CT AGN are intrinsically as abundant as moderately obscured ones (see GCH07), and are predicted to increase dramatically at fluxes below the current sensitivity limits.

§2. Uncertainties on the number of Compton-thick AGN

Since the overall abundance of CT AGN is estimated by subtracting from the XRB spectrum the contribution of Compton-thin sources, it is imperative to estimate the latter at the best of present knowledge. The modeling presented in GCH07 took into account a detailed characterization of the average AGN X-ray spectra, including dispersion, and cosmological evolution, but is nonetheless worth exploring the parameter space to some extent and check how different assumptions may affect the estimated CT number. In the baseline model presented by GCH07, a Gaussian distribution in the AGN primary continuum was considered, with average spectral

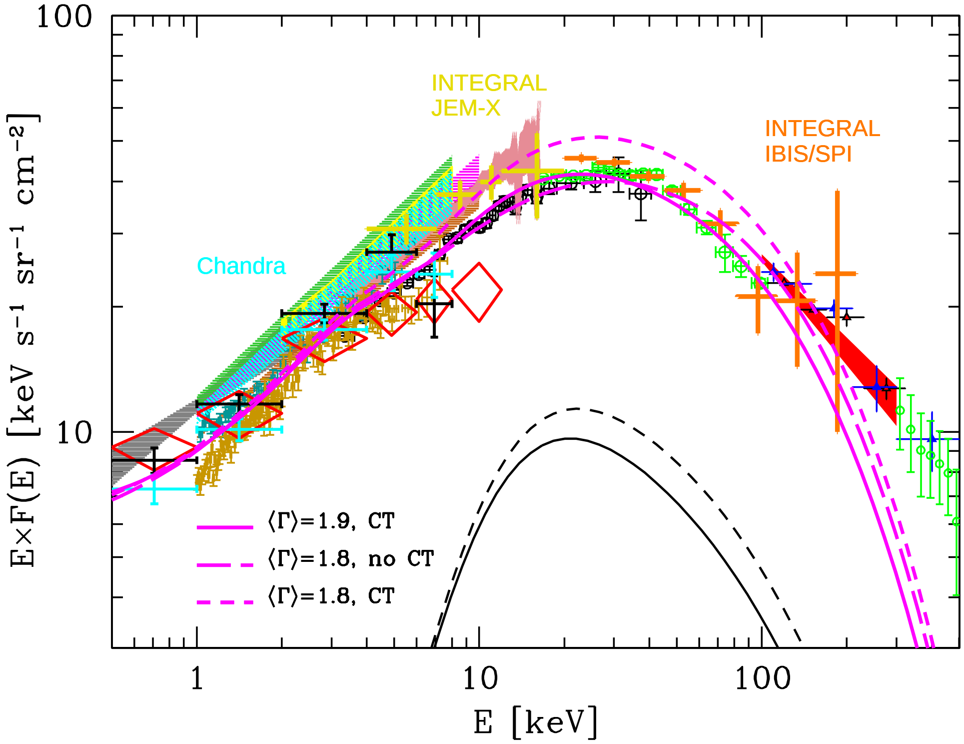

Fig. 2. The spectrum of the X-ray background. Most of the datapoints are described in GCH07. Here we add the recent 5-200 keV measurement by *INTEGRAL* (Churazov et al. 2007) and the 1-7 keV measurement by *Chandra* (Hickox & Markevitch 2006). Model curves based on GCH07 are also plotted: the upper magenta curves show the total contribution from AGN (plus galaxy clusters), according to different assumptions on the average AGN spectral slope and number of CT objects as labeled (see text); the lower black curves represent the corresponding CT contribution.

slope and dispersion of $\langle \Gamma \rangle = 1.9$ and $\sigma_\Gamma = 0.2$, respectively, in agreement with the observed distributions (Mateos et al. 2005). In Fig. 2 we show the effects of assuming an average spectral index $\langle \Gamma \rangle = 1.8$ with the same dispersion. A sligthly harder average spectral powerlaw is in principle sufficient to saturate the XRB emission with Compton-thin AGN, leaving little room for CT sources. Indeed, when adding as many CT AGN as in the baseline model, the 30 keV XRB emission measured by HEAO-1, and recently confirmed within 10% by *INTEGRAL* (Churazov et al. 2007), is exceeded if $\langle \Gamma \rangle = 1.8$. Furthermore, the baseline model appears to be in much better agreement with other observational constraints, such as the spectral distributions observed in different AGN samples and the observed numbers of CT AGN (see GCH07). The model predictions have been further compared with the AGN counts in the 20-40 keV band recently estimated by Beckmann et al. (2006). The situation (Fig. 1 *right*) is similar to that shown in Fig.2 for the XRB, although the constraints are less stringent. While a model with $\langle \Gamma \rangle = 1.8$ would imply a small number of CT AGN, the baseline model provides a good match to the data with a relative ratio of one between Compton-thick and Compton-thin AGN at all redshifts.

This assumed ratio appears more in line with current observations both in the local (Risaliti et al. 1999) and in the distant Universe (Martinez-Sansigre et al. 2006).

§3. The *Suzaku* perspective

To date, about 40 local AGN have been shown to be CT through X-ray observations (Comastri 2004) and their number is expected to increase significantly in the next future. Indeed, CT AGN candidates in current *INTEGRAL* and *Swift* surveys can be easily flagged as such if their X-ray flux above 10 keV is much larger than their soft X-ray flux, which is often available from archival X-ray data. Like *BeppoSAX* in the past years, *Suzaku* is now carrying on board detectors which are sensitive in the broad 0.5-50 keV band and are therefore the ideal instruments to determine the X-ray spectral energy distribution of bright, nearby CT objects. In EAO-1 we have obtained *Suzaku* observations of 2 CT candidates selected from the *INTEGRAL* and *Swift* AGN catalogs (two further candidates will be observed in EAO-2). One of the two objects indeed proved to be CT, while the other turned out to be heavily obscured but still Compton thin (see Comastri et al. this volume, for a more detailed discussion). *Suzaku* observations of additional CT candidates selected above 10 keV are being performed by other groups (e.g. Ueda et al., this volume). Eventually, once these programs are put together to get sufficient object statistics, the fraction of CT AGN in the local Universe will be determined to better accuracy. In particular, new mildly CT AGN should be revealed in significant numbers, and a few spectra of heavily CT AGN, which went undetected by *BeppoSAX*, may be also obtained.

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References

1) V. Beckmann, et al., ApJ **652** (2006), 126.
2) E. Churazov, et al., A&A (2007), in press (astro-ph/0608250).
3) A. Comastri, *Supermassive Black Holes in the Distant Universe* (A.J. Barger, Dordrecht, 2004), p. 245.
4) R. Gilli, A. Comastri and G. Hasinger, A&A **463** (2007), 79. (GCH07)
5) M. Guainazzi, et al., A&A **444** (2005), 119
6) R. Hickox & M. Markevitch, ApJ **645** (2006), 95.
7) A. Marconi, et al., MNRAS **351** (2004), 169.
8) C.B. Markwardt, et al., ApJ **633** (2005), L77.
9) A. Martinez-Sansigre, et al., MNRAS **370** (2006), 1479
10) S. Mateos, et al., A&A **444** (2005), 79.
11) G. Risaliti, R. Maiolino and M. Salvati, ApJ **522** (1999), 157.
12) P. Tozzi, et al., A&A **451** (2006), 457.